Topics

- Holdover and expectations
- Holdover as a system feature
- Oscillator based holdover
- System level challenges
- Deployment models & results

Drive for holdover

1

Demanding applications

- 5G performance
  – carrier aggregation
- URLLC
  – reliability & availability

2

GNSS vulnerability

- Jamming
- Spoofing
- Weather & other environmental
- Deployment inaccuracies

3

New network architectures

- Distributed & open architectures
- Generic equipment designs
- Superset of Sync configurations

4

Challenging deployments

- Application scenarios
- Partial on-path support networks
- End system specifications

Expectations on holdover performance

5G air interface alignment Carrier aggregation	±130 ns to ±1.5 µs across radios
TSN Networks Industrial Networks Automotive Networks	1 µs end to end
Financial Networks	400 ns – 1 µs
Data Center Networks	5 µs (OCP-TAP)

Methods of achieving holdover

GNSS based reference

- Is most common primary source of reference

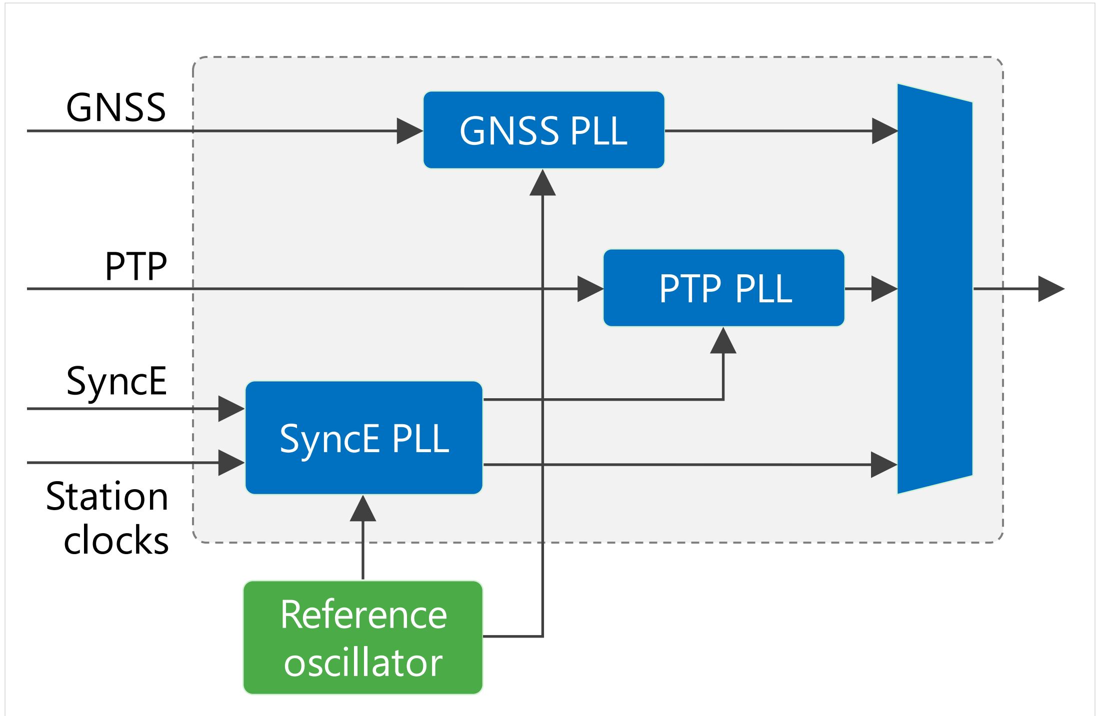
Holdover in various forms

- PTP holdover
- SyncE holdover
- Oscillator Holdover

Oscillator holdover

- Default backup

Typical servo implementation



Holdover theory

Phase Holdover At Time (t): $x(t) = x_o + (f_o + \text{average}(\Delta f_{env} + \Delta f_{HT} + \Delta f_{RW}))*t + ½* \Delta f_{age} * t^2$

x_o = Initial phase offset
fo: The initial fractional frequency offset (ppb)

The "Servo Error"

Δf_{env}: sum total of the changes in frequency (ppb) due to environmental factors
(including temperature, input voltage, output loading, pressure, humidity, acceleration etc.)

$\Delta f_{Age:}$ Systematic deviation over time

$\Delta f_{HT:}$ Effect of hysteresis on holdover

Δf_{RW}: Random frequency noise not associated with environmental effects or long term aging
Aging: The long term change in frequency over time (ppb/day)

Additional factors affecting holdover

Micro Jumps & activity dips	Short jumps on frequencies are caused by the resonators and construction; Activity dips are changes in frequencies at a certain temperature points
Airflow	Causes frequency variations
Shock & Vibration	Causes frequency deviation for the period of vibration

Traditional methods of extension

Methods

Temperature characterization

Use temperature sensors near the oscillator and study the behaviour across temperature

Ageing Estimation

Measure Oscillator using network reference

Estimating hysteresis

Use the temperature characterization data to estimate hysteresis

Estimate random behaviour

Use the generalized numbers provided by oscillator manufacturer

Challenges

Operationally intensive

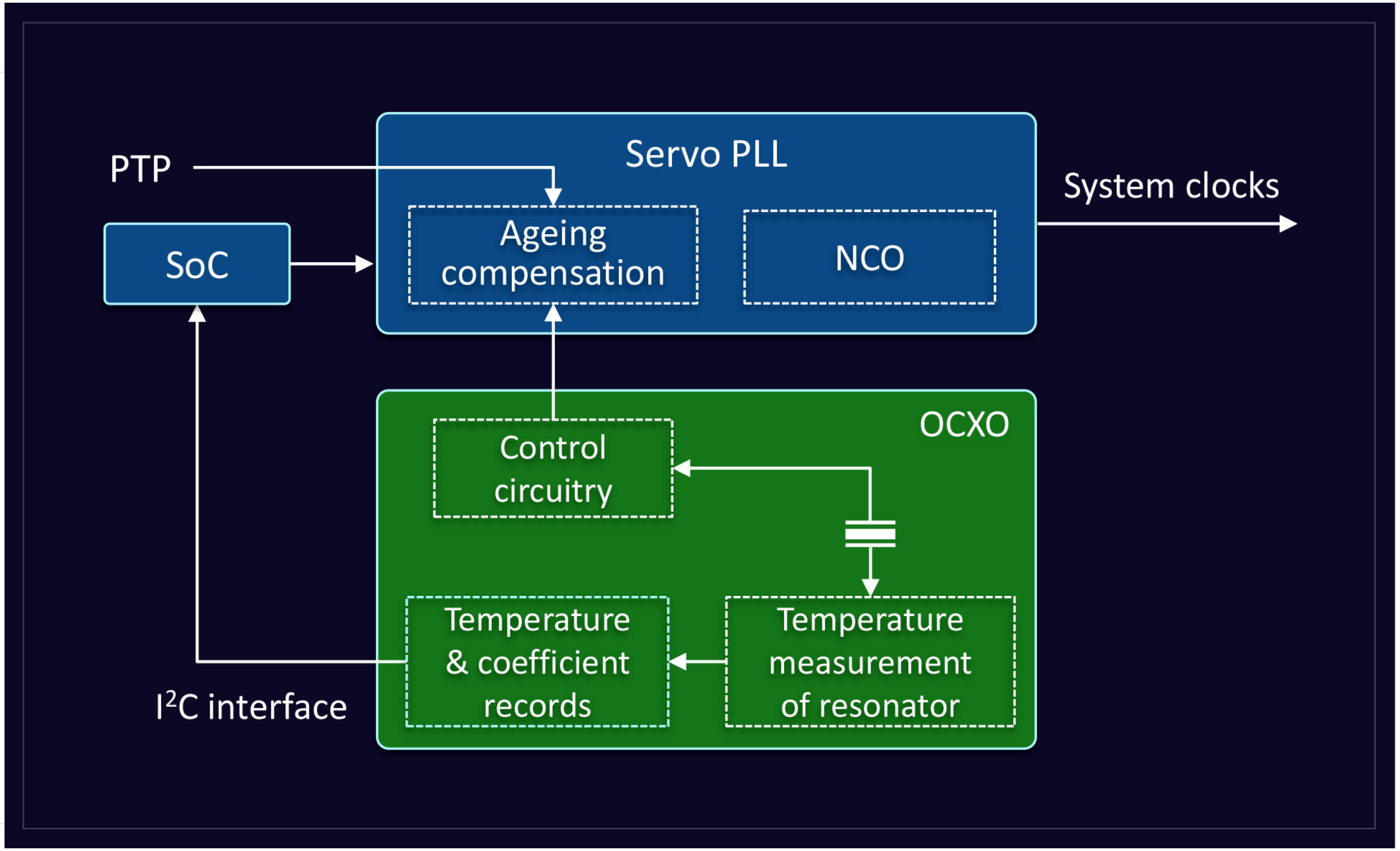
- Temperature cycling individual equipment to recover frequency characterization over temperature

Separating components

- Extract ageing along when temperature change involved
- Ageing random behaviours when change related to ageing involved

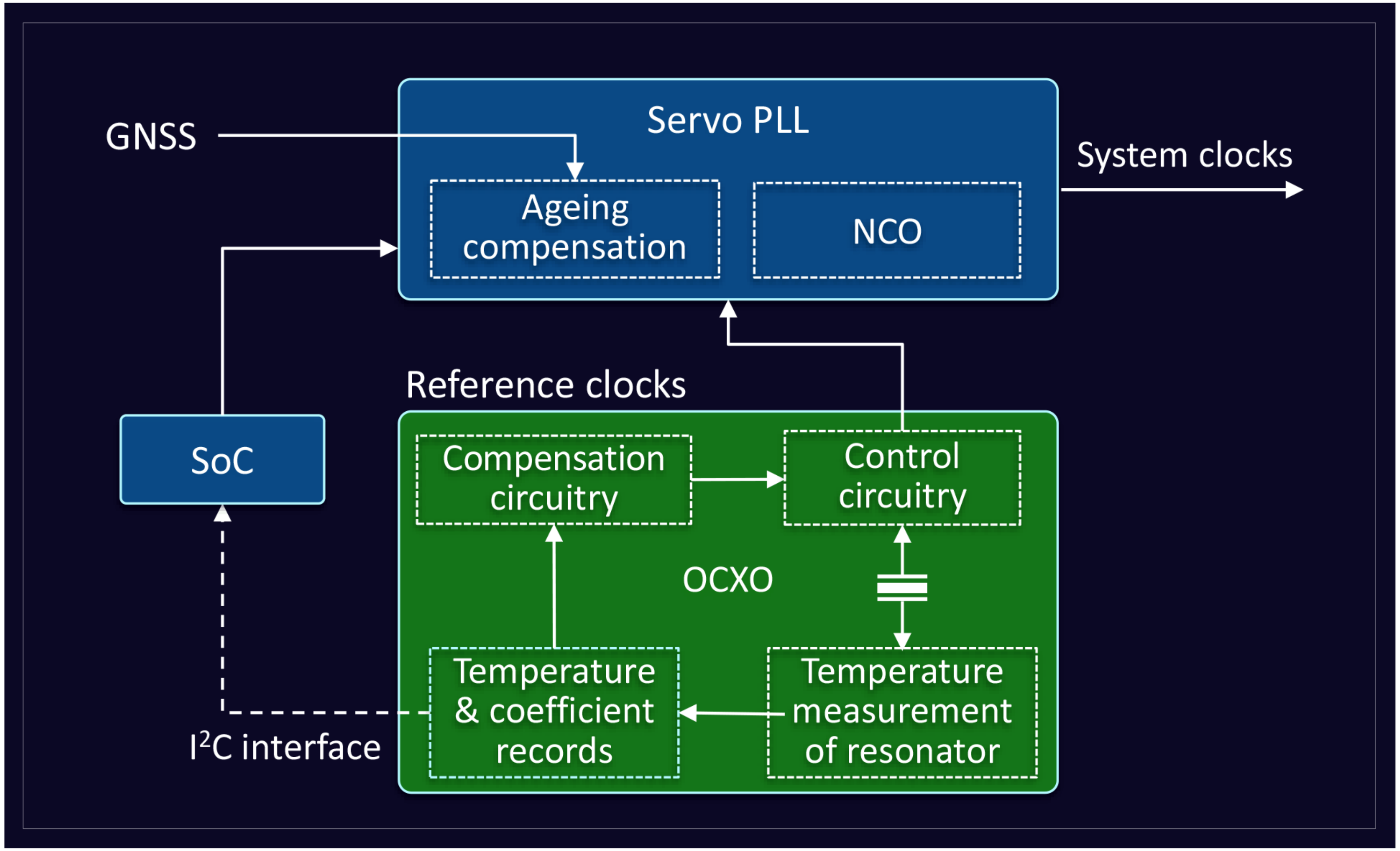
OCXOs with temperature coefficients

Frequency references providing frequency coefficients of temperature change



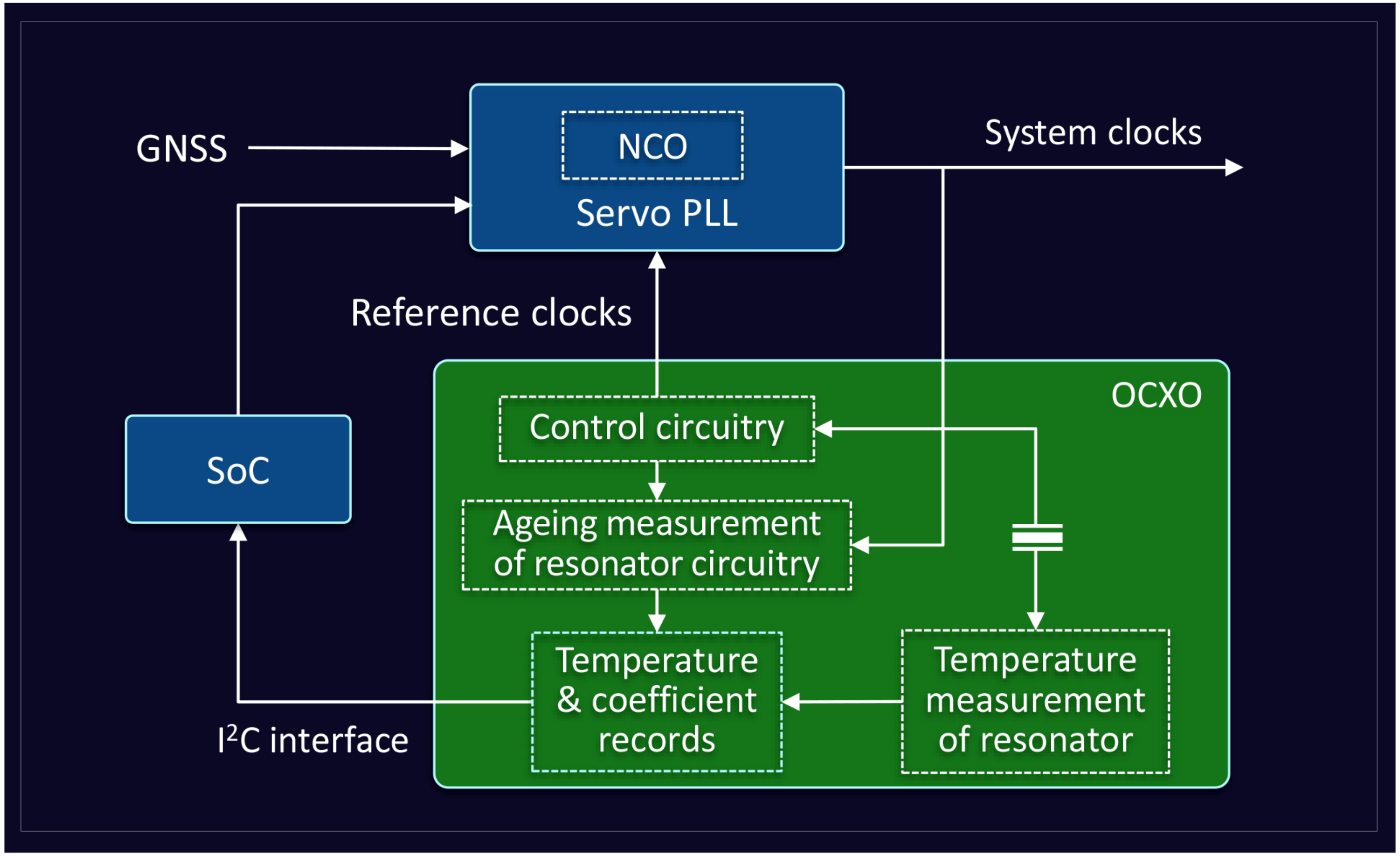
Post Compensated Clocks

Frequency references integrating temperature compensation



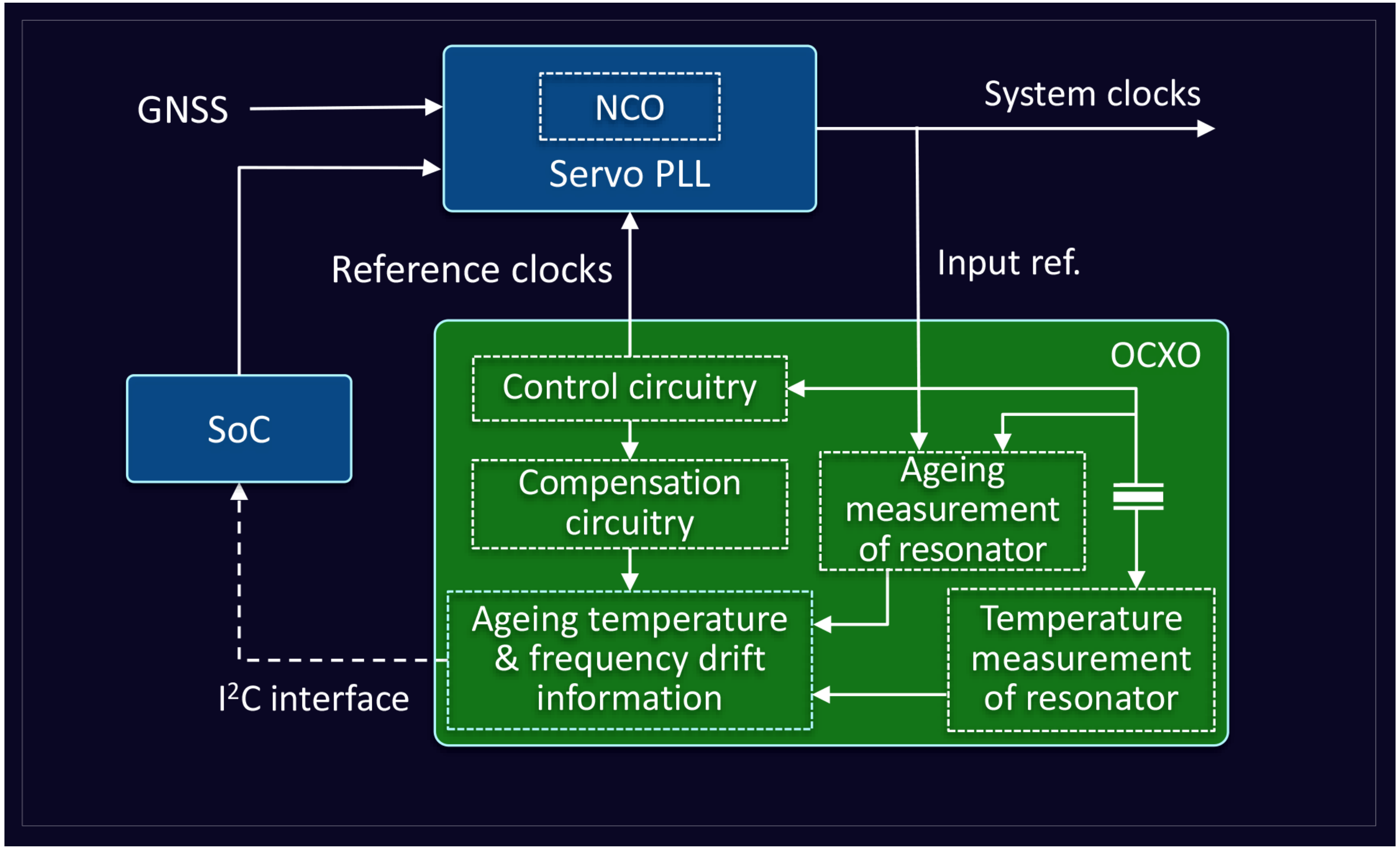
Clocks with error frequency outputs

Clocks providing frequency coefficients of temperature changes & ageing



Integrated Ageing & Temperature Compensation

Clocks compensate for temperature variations and ageing



Challenges

1

Standard footprints

25 x 22 mm oscillators are industry standard

2

Common crystal resonator

High reliable and good performance HC43 resonators

3

Manufactural thermal package

Special designs

Avoiding double ovens

4

Production Compliance

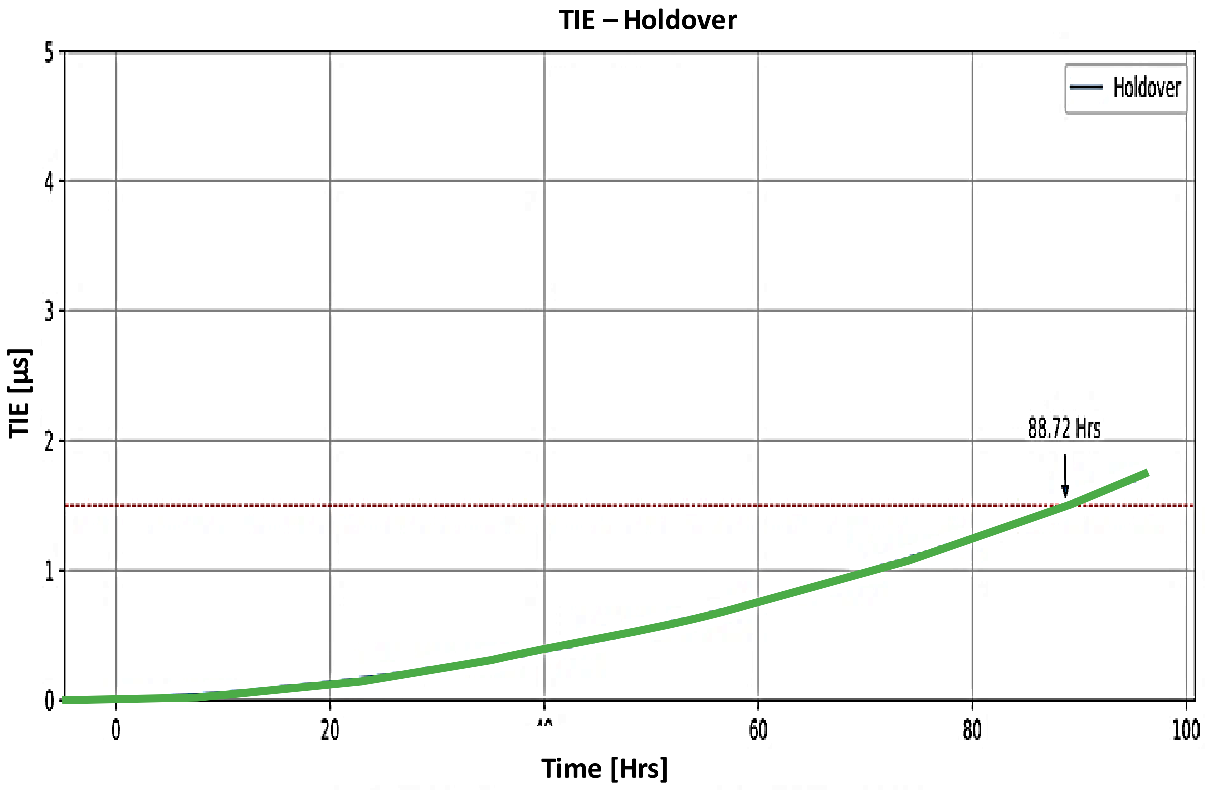
Custom testing flow for mass manufacturing

5

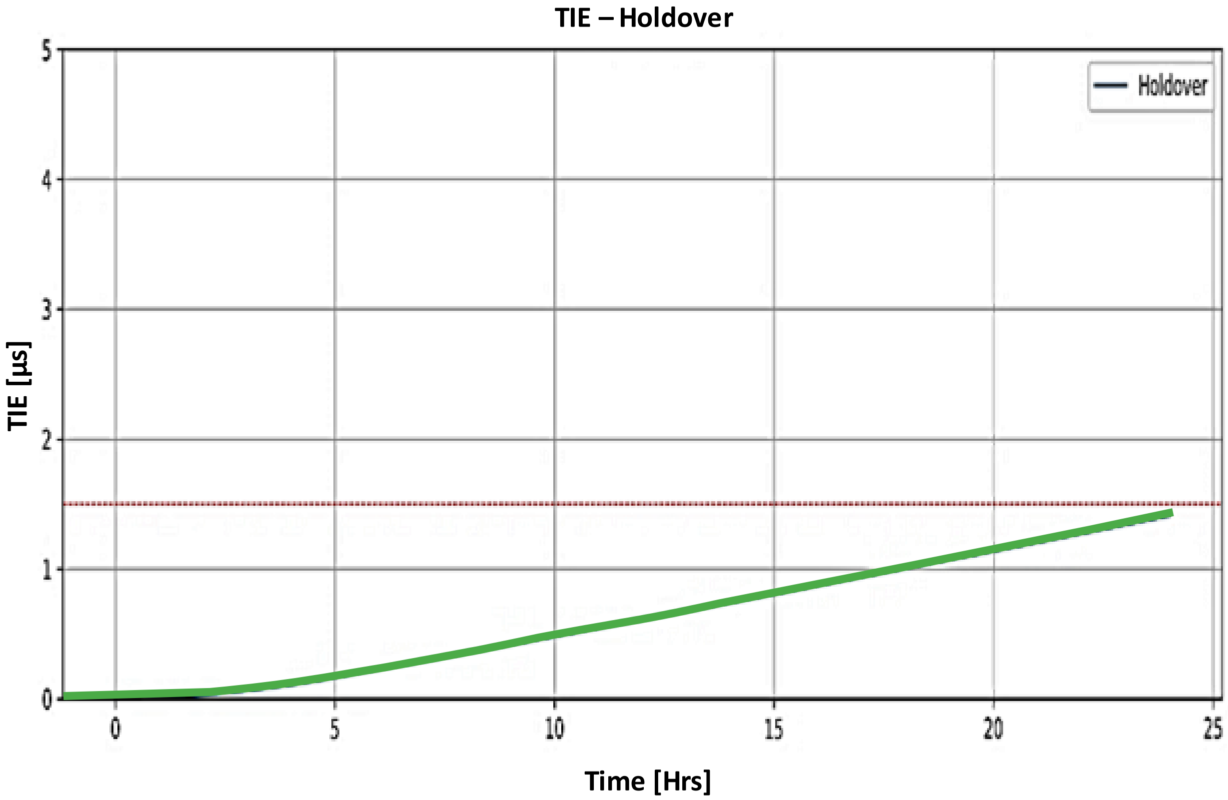
Commercial viability

Price!

24-hour holdover evaluations



Constant temperature: 1.5 µs / >88 hrs



4°C temperature ramp at 0.8°C/hour rate >24 hrs

Summary

- Holdover is increasingly prominent in new networks
- GNSS vulnerability is real
- Various deployment techniques with oscillators
- Temperature error, frequency error outputs and integrated devices
- 24-hour holdover devices are possible
- On a 25 x 22mm industry standard package

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